Visual Acuity and the Causes of Visual Loss in Australia

The Blue Mountains Eye Study

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Background: The Blue Mountains Eye Study is a population-based study of vision and the causes of visual impairment and blindness in a well-defined urban, Australian population 49 years of age and older.

Methods: The logarithm of the minimum angle of resolution (logMAR) visual acuity was measured before and after refraction in 3647 persons, representing an 88% response rate in two postcode areas in the Blue Mountains area, west of Sydney.

Results: Refraction improved visual acuity by one or more lines in 45% of participants and by three or more lines in 13%. Visual impairment (visual acuity 20/40 or worse in the better eye) was found in 170 participants (4.7%). Mild visual impairment (Snellen equivalent 20/40 to 20/60 in the better eye) was found in 3.4%, moderate visual impairment (20/80 to 20/160 in the better eye) in 0.6%, and severe visual impairment or blindness (20/200 or worse in the better eye) in 0.7%. Visual impairment increased with age from 0.8% of persons 49 to 54 years of age to 42% of persons 85 years of age or older. Visual impairment was significantly more frequent in females at all ages. Among persons with severe visual impairment, 79% were female. After adjusting for age, females were less likely to achieve 20/20 best-corrected visual acuity than males (odds ratio, 0.57; confidence interval, 0.48–0.66). After adjusting for age and sex, no association was found between visual acuity and socioeconomic status. Age-related macular degeneration was the cause of blindness in 21 of the 24 persons with corrected visual acuity of 20/200 or worse.

Conclusion: Increasing age and female sex were independent predictors of visual impairment. *Ophthalmology 1996;103:357–364*

Visual acuity is a measure of the eye's ability to resolve fine detail and is the usual test of visual function in standard eye examinations. There are few current population-based estimates of best-corrected visual acuity and the causes of visual impairment in older populations. In Australia, as in other western communities, the elderly represent the fastest growing sector of the population. The proportion of Australians 65 years of age and older is expected to double from its current 11% to 21% in the year 2031.[1] Baseline measurements of the frequency and causes of visual impairment and the frequency of treatable visual loss are required to plan future eye care needs. Despite increasing longevity in Australia, disability-free life expectancy is not increasing.[2] Further, visual impairment contributes to the loss of independence in older age. Existing data from Blind Pension registrations or attendance to blind agencies[3–6] are likely to give an incomplete picture of visual impairment. The Blue Mountains Eye Study was designed to assess visual acuity and the causes of visual impairment in a representative older urban population.

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Patients and Methods

Patients

Ethical approval for the study was obtained from the Western Sydney Area Health Service. Two adjoining urban postcode areas in the Blue Mountains area, west of Sydney, in New South Wales, Australia, were selected as the target population. This target population was chosen because it has an older age distribution than the state average and is geographically well defined, enhancing the potential for community support and publicity. This area has a relatively stable and homogenous population that is representative of the state of New South Wales for income and socioeconomic status.[7] A door-to-door census was conducted by trained interviewers from November to December 1991 for the first postcode area and from March to April 1993 for the second postcode area, using Australian National Census maps for 38 individual census districts.[7] Each census was preceded by local publicity and notification by mail to each dwelling. All noninstitutionalized, permanent residents born before January 1, 1943, at the time of the census were eligible. This included persons 49 years of age or older, with no upper age limit. Permanent residents were defined as living in the dwelling for more than 6 months of the year.

Call-back visits to each house were made until contact with a resident occurred, either by doorknocking or telephoning, using an electronic directory sorted by street. Final classification as "no contact" was made after at least five separate calls to the house at different times of the day and different days of the week and at least three letters to the household identified no eligible residents. Nursing home residents were counted for comparison with the Australian National Census but excluded from analysis because the survey area is over-represented by nursing homes. A sample of 134 nursing home residents was examined and will be the subject of a separate report.

Procedures

Interviewers administered a short questionnaire to eligible residents. This questionnaire included self-reported vision or hearing problems and a past diagnosis of cataract, glaucoma, macular degeneration, diabetes, or hypertension. Last attendance to an ophthalmologist or optometrist also was recorded. A detailed information sheet about the Eye Study was given or sent to each eligible resident. Subsequently, all identified eligible residents were invited to attend a clinic at the local hospital. At the clinic, informed consent was obtained from each participant, and trained interviewers completed a comprehensive demographic and medical questionnaire. Examinations began in January 1992 and were completed in December 1993.

At the clinic visit, visual acuity was measured using a logarithm of the minimum angle of resolution (logMAR) chart. The chart was retro-illuminated with automatic calibration to 85 cd/m^2 (Vectorvision CSV-1000™, Vectorvision, Inc, Dayton, OH) and read at 8 ft (244 cm). Three measurements of distance visual acuity were performed for each eye. Visual acuity was assessed initially using current distance glasses if worn, then with a 1.2-mm pinhole aperture held over the current distance glasses, and finally after subjective refraction. Refraction was performed if initial visual acuity was less than 54 letters read correctly (20/20 Snellen equivalent). Best-corrected visual acuity was defined as the visual acuity after subjective refraction in the participant's better eye.

A Humphrey autorefractor (Model 530) was used to obtain an objective refraction. Subjective refraction then was performed according to the Beaver Dam Eye Study modification of the Early Treatment Diabetic Retinopathy Study protocol.[8,9] For each eye, visual acuity was recorded as the number of letters read correctly from 0 (<20/20) to 70 (20/10). If no letters could be read at 8 feet (244 cm), the chart was moved to 3 feet (91 cm), giving the four extra levels of visual acuity recorded: 20/250, 20/300, 20/400, 20/500. If no letters could be identified on the chart, the visual acuity was assessed as count fingers at 2 feet (61 cm), hand movements, perception of light, or no perception of light.

Height, weight, blood pressure, and Goldmann applanation tonometry were measured. Automated perimetry was performed in both eyes using the Humphrey 76-point test. People failing this test were subsequently retested using the Humphrey 30-2 test. Pupils were dilated using tropicamide 1.0% and phenylephrine 10%, and a detailed dilated examination was conducted on all subjects. This included slit-lamp and retro-illumination photographs of the lens and Zeiss stereoscopic photographs of the optic disc and retina. Assignment of the proportional causes of visual loss for each eye was made by the examining ophthalmologist (PM) at the end of the examination. Confirmation of these causes was made during grading of the lens and retinal photographs.

Definitions of Visual Impairment Levels

The four levels of visual impairment were defined using the best-corrected visual acuity in the better eye as follows: (1) no visual impairment defined as a Snellen equivalent better than 20/40 visual acuity (41–70 letters read correctly), (2) mild visual impairment defined as 20/40 to 20/63 visual acuity (26–40 letters read correctly), (3) moderate visual impairment defined as 20/80 to 20/160 visual acuity (6–25 letters read correctly), and (4) severe visual impairment defined as 20/200 or worse visual acuity (0–5 letters read correctly).

Eligibility for the blind pension in Australia is defined as a Snellen vision in the better eye of less than 20/200 or a functional visual field of less than 10°,[10] although no participants were eligible using the second criterion.

Definitions of Unilateral Visual Impairment

The three levels of unilateral visual impairment were defined as follows: (1) mild defined as 20/40 to 20/63 visual acuity in the worse eye and >20/40 visual acuity in the better eye, (2) moderate defined as 20/80 to 20/160 visual acuity in the worse eye and >20/80 in the better eye, and

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Table 1. Comparison of Selected Characteristics for Participants and Nonparticipants

Characteristics	Participants (%) (n = 3654)	Nonparticipants* (%) (n = 780)	
Female	56.7	54.8 (754)	
Male	43.3	45.2 (754)	
Wears glasses†	97.2	55.1 (544)	
Cannot read newspaper while wearing eyeglasses	7.9	6.3 (539)	
Cannot recognize friend across street	5.4	4.2 (534)	
Age			
<60	27.9	30.3	
60–69‡	35.8	26.8	(641)
70–79	26.3	25.9	
80+	10.0	16.8	
History of			
Cataract	16.5	15.7 (553)	
Glaucoma	6.0	4.9 (553)	
AMD	2.4	3.8 (549)	
Hypertension‡	40.5	35.7 (530)	
Diabetes	6.8	6.0 (531)	
Ever seen ophthalmologist†	49.0	56.0 (521)	

AMD = age-related macular degeneration.

* Number of nonparticipants who answered question are in parentheses.

† $P < 0.01$.

‡ $P < 0.05$.

(3) severe defined as 20/200 or less visual acuity in the worse eye and >20/200 visual acuity in the better eye.

For comparison with results from the Beaver Dam Eye Study, these definitions were modified to include no visual impairment (>20/40 visual acuity in the better eye) for all categories.

Data Handling and Statistical Analysis

Data were entered into DBASE IV (Borland International Inc, Scotts Valley, CA) using automatic skips and range checks. Statistical Analysis System[11] was used for all statistical analyses. Unpaired and paired Student's *t* tests were used to compare differences in continuous response (mean number of letters correct) between specific groups of persons and between eyes. Chi-square and logistic regression statistics were used to compare frequency distributions of visual acuity categories. All population means are reported with their standard deviation, and all mean differences are reported with their standard error. All confidence intervals presented are 95% confidence intervals.

Results

Patients

Of 5103 occupied dwellings, there were 2885 with age-eligible noninstitutionalized permanent residents. During the census and after its completion, 4433 eligible residents were identified. In addition, 625 residents with birthdates before January 1, 1943, were identified as living in eight nursing homes in the two postcode areas studied. However, as the survey was limited to free-living residents, these people were not included in the present study. The number of eligible residents found in the study census in the two postcode areas differed by only 0.15% from the recent Australian national census, conducted 3 months earlier.[7] Of the 4433 eligible residents, 3654 (82.4%) participated in the examinations, of whom 99% were white. The participants ranged in age from 49 to 97 years with more females seen in all age groups. A total of 501 persons (11.3%) refused to participate, of whom 353 (8.0%) permitted a brief interview about their visual acuity and any history of eye disease, and 148 people (3.3%) refused both the examination and interview.

When the study coordinator contacted eligible households to arrange clinic appointments, 68 persons (1.5%) had died and 210 (4.8%) had moved from the area. Thus, a total of 278 persons (6.3%) identified in the census could not be examined. After excluding this group, a response rate of 87.9% was achieved. This response rate compares favorably with other recent surveys of visual acuity, including the Beaver Dam Eye Study,[12] 87.8%; Baltimore Eye Survey,[13] 79.2%; and the Framingham Eye Study,[14] 66.2%.

A comparison of some differences between participants and non-participants is listed in Table 2. Non-participants were less likely than participants to wear glasses, an obvious self-selection bias. Non-participants also were significantly more likely to have seen an ophthalmologist. Symptomatic visual impairment was not significantly higher among participants, but the prevalence of chronic systemic diseases (hypertension and diabetes) was slightly more common among participants. There was no significant difference in the proportion of females among participants compared with non-participants. The age profile showed an over-representation of those older than 80 years not participating (26% for persons 80 years old or older compared with 16% for persons younger than 60 years old).

Table 2. Improvement in Visual Acuity after Subjective Refraction

No. of Lines of Improvement	Right Eye (%)	(95% CI)	Left Eye (%)	(95% CI)
1 line (5–9 letters)	20.3	(19.0–21.6)	20.0	(8.7–21.3)
2 lines (10–14 letters)	12.0	(10.9–13.0)	10.5	(9.5–11.5)
≥3 lines (15–64 letters)	13.0	(11.9–14.0)	11.6	(10.6–12.6)
Total	45.3	(43.7–46.9)	42.1	(40.5–43.7)

CI = confidence interval.

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Table 3. Percentage Distribution of Unilateral Visual Impairment* by Age and Sex in the Blue Mountains Eye Study (1992–1993) Compared with the Beaver Dam Eye Study (1988–1990)

Sex	Age† (yrs)	No. in the BMES	No. in the BDES	Mild Impairment, BMES	Mild Impairment, BDES	Moderate Impairment, BMES	Moderate Impairment, BDES	Severe Impairment, BMES	Severe Impairment, BDES
Female	49–54	270	794	2.2	2.1	0.0	0.5	0.7	1.0
	55–64	659	698	2.9	5.2	0.6	1.1	0.9	1.1
	65–74	681	738	5.1	10.6	1.5	2.3	1.2	1.9
	75–84	373	510	14.5	20.6	3.5	3.9	2.9	2.0
	85+	85		17.6		4.7		5.9	
	Total	2068	2740	6.2	8.6	1.5	1.8	1.5	1.5
Male	43–54	215	721	0.9	1.8	0.0	0.6	1.9	1.5
	55–64	513	611	1.9	2.9	0.2	0.8	1.9	2.5
	65–74	526	540	5.7	7.8	2.1	2.0	3.8	2.8
	75–84	278	285	15.5	18.2	2.9	2.5	4.7	4.2
	85+	47		14.9		6.4		10.6	
	Total	1579	2157	5.8	5.8	1.5	1.3	3.3	2.5
All	43–54	485	1515	1.6	2.0	0.0	0.5	1.2	1.3
	55–64	1172	1309	2.5	4.1	0.4	1.0	1.4	1.8
	65–74	1207	1278	5.4	9.4	1.7	2.2	2.3	2.3
	75–84	651	795	14.9	19.7	3.2	3.4	3.7	2.8
	85+	132		16.7		5.3		7.6	
	Total	3647	4897	6.1	7.4	1.5	1.6	2.3	1.9

BMES = Blue Mountains Eye Study; BDES = Beaver Dam Eye Study.

* Mild: worse eye, 20/40–20/63 and better eye, better than 20/40; moderate: worse eye, 20/80–20/160 and better eye, better than 20/40; severe: worse eye, 20/200 or worse and better eye, better than 20/40.

† BMES age range, 49–97 years; BDES age range, 43–86 years.

Distance Vision

Best-corrected visual acuity could be assessed accurately for 3,647 people. Visual acuity was not obtainable in seven people. Of these, two underwent short examinations with no subjective refraction, three refused visual acuity measurement, and two had dementia.

After subjective refraction, distance vision could be improved by one line of the chart, or 6.0 ± 0.13 letters (average ± standard error) in the right eye and 5.4 ± 0.12 letters in the left eye. Overall, 45.3% of participants improved by one or more lines in the right eye, including 20.3% improving by one line, 12% by two lines, and 13% by three or more lines (Table 3).

The mean number of letters read correctly was slightly higher in the left eye (51.5 ± 12.4 letters; $P = 0.01$) compared with the right eye (51.0 ± 13.2 letters; $P = 0.01$). In the first 1868 participants examined, the same chart was used for both eyes. In this group, the left eye read 0.5 ± 0.30 letters (average ± standard error) better than the right eye. However, this was not statistically significant ($P = 0.12$). For the remaining 1779 participants, different charts were used for right and left eyes. The difference persisted with the left eye reading on average 0.6 ± 0.32 letters better than the right ($P < 0.05$).

The prevalence of corrected visual acuity of 20/20 or better (54 or more letters read correctly) declined in both eyes with increasing age (Fig 1). The prevalence of 20/20 visual acuity in persons 49 to 54 years of age (93.4%) was more than 10 times the prevalence in people 85 years of age or older (9.1%). Females were significantly less likely than males to have 20/20 or better visual acuity, after adjusting for age as a continuous variable in a logistic regression, odds ratio 0.57 (0.48–0.66). Age-adjusted mean visual acuity scores were significantly lower in females, who correctly identified on average 2 fewer letters than males ($P < 0.0001$). Visual acuity declined with increasing age in both sexes from 56 ± 5.9 letters (mean ± standard

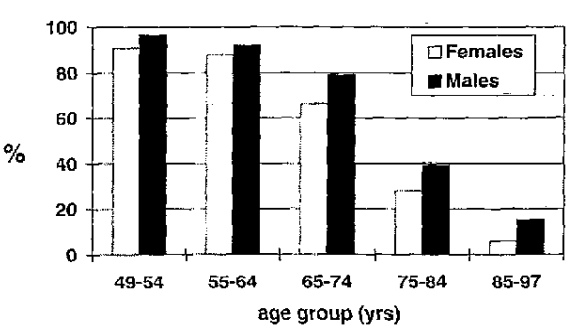

Figure 1. Prevalence of 20/20 visual acuity by age and sex.

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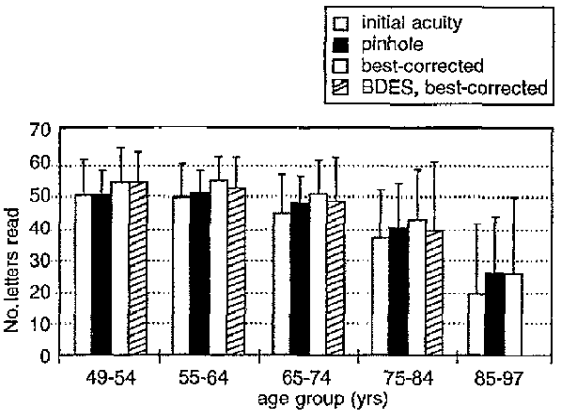

Figure 2. Mean visual acuity (error bars = standard deviation) by age in females. BDES = Beaver Dam Eye Study.

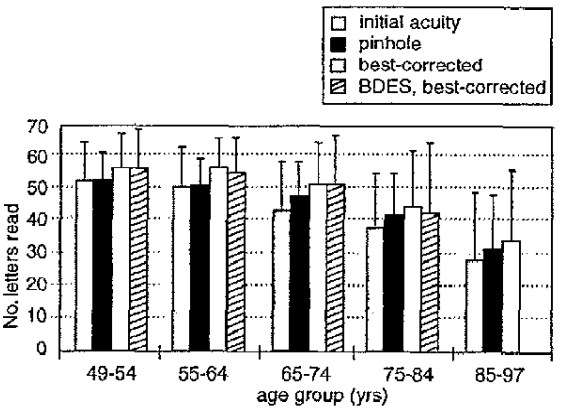

Figure 3. Mean visual acuity (error bars = standard deviation) by age in males. BDES = Beaver Dam Eye Study.

deviation) in women (20/20 plus 1 letter) and 58 ± 4.3 letters in men (20/20 plus 3 letters) in the 49- to 54-year age group to 30 ± 21.4 letters (20/63 visual acuity) and 35 ± 20.8 letters (20/50 visual acuity), respectively, in the 85+ age group (Figs 2 and 3). Visual acuity after subjective refraction was 3.5 ± 0.09 letters (average ± standard error) (better than through a pinhole for the right eye ($P < 0.0001$) and 3.4 ± 0.09 letters better for the left eye ($P < 0.0001$). Corrected mean logMAR visual acuity scores were very similar to those found in the U.S. Beaver Dam Eye Study,[12] using the same age and sex categories.

Prevalence and Causes of Blindness and Visual Impairment

Visual impairment was assessed for the better of the two eyes (Table 4). Higher proportions of mild, moderate, and severe visual impairment were found in each age group in women compared with men ($P < 0.0001$). For women in the older age group (range, 75–84 years), 3.7% (95% CI, 1.8–5.6) had moderate or severe visual impairment. Among women 85 to 97 years of age, 16.5% (95% CI, 8.6–24.4) had moderate or severe visual impairment. Among men in the older age group (range, 75–84 years), moderate or severe visual impairment was present in 2.5% (95% CI, 0.7–4.3) and in 8.5% (95% CI, 0.5–16.5) of those 85 to 97 years of age.

Severe visual impairment (5 or less letters read at 2.4 m from the chart, equivalent to ≤20/200 visual acuity) was found in 24 persons (19 females, 5 males), or 0.7% of the population. Using the World Health Organization definition of blindness (<20/400), 10 persons (9 females, 1 male), or 0.27%, were blind. Using the level for legal blindness and blind pension benefits in Australia[6] (<20/200 or 3 letters or less), 17 persons (15 females, 2 males) or 0.5% of the population were blind.

The principal cause for blindness was defined as the major cause of visual loss in the second eye. Eyes were designated "first" or "second" based on the temporal sequence of vision loss. Age-related macular degeneration (AMD) was the main cause in 21 of the 24 persons (88%). The remaining three persons were blind from cataract, occipital infarct, or central retinal vein occlusion. Secondary causes of visual loss in the second eye included cataract (10 patients) and glaucoma (2 patients). In 16 of the 21 persons blind from AMD, this disease also was the cause for blindness in their first eye. Of these, 38% (6/16) had exudative macular degeneration in both eyes, 31% (5/16) had pure geographic atrophy in both eyes, and 31% (5/16) had exudative degeneration in one eye and pure geographic atrophy or a mixture of exudative degeneration and geographic atrophy in the other eye. Other diseases causing blindness in the first eye included cataract (4 patients), keratitis, retinal detachment, and postoperative endophthalmitis.

Moderate visual impairment was found in 21 persons, or 0.6% of the population. The main cause was AMD in eight (38%), cataract in seven (33%), glaucoma in two (10%), and one patient each with diabetic retinopathy, congenital nystagmus, postoperative astigmatism, and keratitis (19%). Secondary causes in the second eye were cataract in six persons and AMD in five persons. In the first eye of persons with moderate visual impairment, AMD and cataract were the most frequent causes of decreased vision in ten and seven patients, respectively. Of persons with AMD in both eyes, 50% (4/8) had exudative degeneration in both eyes, 38% (3/8) had pure geographic atrophy in both eyes, and 12% (1/8) with pure geographic degeneration in one eye and a mixture of geographic atrophy and exudative degeneration in the other.

Mild visual impairment was found in 125 persons, or 3.4% of the population. The main causes were cataract and age-related maculopathy. Cataract was the main cause in 94 persons (74%), age-related maculopathy in 21 persons (17%), and glaucoma and posterior capsule opacification in 3 persons each. A number of diseases including myopic retinopathy, severe hypermetropia, secondary choroidal neovascularization, and toxoplasmosis were the remaining causes. Major causes for visual impairment in

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Table 4. Percentage Distribution of Visual Impairment* by Age and Sex in the Blue Mountains Eye Study (1992–1993) Compared with the Beaver Dam Eye Study (1988–1990)

Sex	Age† (yrs)	No. in the BMES	No. in the BDES	Mild Impairment, BMES	Mild Impairment, BDES	Moderate Impairment, BMES	Moderate Impairment, BDES	Severe Impairment, BMES	Severe Impairment, BDES
Female	49–54	270	794	1.1	0.6	0.4	0.1	0	0.1
	55–64	659	698	0.9	0.4	0.2	0.3	0	0.1
	65–74	681	738	2.1	5.2	0.4	0.3	0.1	0.4
	75–84	373	510	9.1	16.3	1.3	5.1	2.4	2.6
	85+	85		32.9		5.9		10.6	
	Total	2068	2740	4.1	4.7	0.7	1.1	0.9	0.7
Male	49–54	215	721	0	0.6	0	0	0	0.1
	55–64	513	611	0.2	0.7	0	0	0	0.2
	65–74	526	540	1.7	3.2	0	0.6	0	0.2
	75–84	278	285	7.6	13	1.4	2.1	1.1	1.1
	85+	47		19.1		4.3		4.3	
	Total	1579	2157	2.5	2.9	0.4	0.4	0.3	0.3
All	49–54	485	1515	0.6	0.6	0.2	0.1	0	0.1
	55–64	1172	1309	0.6	0.5	0.1	0.2	0	0.2
	65–74	1207	1278	1.9	4.3	0.2	0.4	0.1	0.3
	75–84	651	795	8.4	15.1	1.4	4	1.8	2
	85+	132		28		5.3		8.3	
	Total	3647	4897	3.4	3.9	0.6	0.8	0.7	0.5

BMES = Blue Mountains Eye Study; BDES = Beaver Dam Eye Study.

* Mild = 20/40–20/63 visual acuity; moderate = 20/80–20/160 visual acuity; severe = 20/200 or worse visual acuity.

† BMES age range, 49–97 years; BDES age range, 43–86 years.

the first eye of this group included cataract in 81 persons, age-related maculopathy in 22, and glaucoma in 5.

Unilateral Visual Impairment

The frequency of severe unilateral visual impairment increased with age. Two definitions of unilateral visual impairment were used. The first definition includes people with visual impairment in one eye and less or no impairment in the other eye. The second definition includes people with visual impairment in one eye and no impairment in the other eye to enable close comparison with results from the Beaver Dam Eye Study.[12]

Using the first definition, 120 people (3.3%) had severe unilateral visual impairment and a significant difference was found between right and left eyes, with 71 right eyes blind compared with 49 left eyes ($P < 0.001$). Males were more likely than females, odds ratio 1.52 (CI, 1.05–2.19), to have severe unilateral visual impairment. The causes of unilateral visual impairment are shown in Table 5. Using the second definition, 84 persons (2.3%) had severe unilateral visual impairment, which affected males more frequently than it did females, odds ratio 2.27 (CI, 1.45–3.55), largely due to the effect of unilateral trauma.

Discussion

Good vision is a major component in maintaining quality of life with increasing age. Deterioration of vision threatens independence and an active lifestyle by affecting abilities such as reading and driving. Good vision also assists older individuals to avoid accidental falls and associated fractures.[15]

This study found that in 45% of participants, visual acuity could be improved by one or more lines, and in 13%, visual acuity could be improved by three or more lines on the vision chart, simply by a change in distance glasses prescription. Previous studies[12] also have found a significant proportion of impaired vision due to refractive under-correction. In the Baltimore Eye Survey,[13] 54% of subjects improved their vision by at least one line and 7.5% by three or more lines. A London survey[16] found that 27% of the population studied 65 years of age or older would benefit from a change in refractive correction. Explanations for this widespread refractive undercorrection in the community may include the high cost of new frames and lenses for some or, more likely, simply a desire not to wear glasses. Some people go to great lengths not to wear spectacles.[17] A concern is the belief of many elderly people that worsening vision is a normal part of growing older.[18]

The Visual Acuity Impairment Survey pilot study attempted to use pinhole vision in place of subjective refraction to save time during the assessment of patients.[19,20] However, the Visual Acuity Impairment Survey found that 26% of participants who failed to read the 20/40 visual acuity line using a pinhole disc could read 20/40 visual

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Table 5. Causes of Severe Unilateral Visual Impairment in the Blue Mountains Eye Study (1992–1993)

Causes of Unilateral Blindness	No.
Age-related macular degeneration	30
Cataract (age-related, 24; congenital, 1)	25
Amblyopia	16
Ocular trauma	12
Retinal vein occlusion (central, 6; branch, 3)	9
Glaucoma (open angle, 3; closed angle, 1; secondary, 2; rubeotic, 2)	8
Retinal detachment	6
Anterior ischemic optic neuropathy	3
Central retinal artery occlusion	2
Choroidal neovascularization (non-age-related)	2
Chorioretinitis	2
Corneal graft rejection	2
Diabetic retinopathy	1
Keratitis	1
Premacular fibrosis	1
Total	120

acuity or better after refraction according to a standardized protocol. The Blue Mountains Eye Study has confirmed that subjective refraction will achieve significantly better vision than through a pinhole aperture, with almost one line (three to four letters) average better acuity. This finding emphasizes the need to include subjective refraction in studies for which vision is a major end point.

Rates of blindness and visual impairment have been documented to sharply increase with age, beginning at around 65 years.[12,13,21–23] Blindness rates documented in this Australian study are comparable with the rates found in similar U.S. studies, after taking into account differences in the definition of blindness.

The overall visual acuity findings in the Beaver Dam Eye Study from Wisconsin were very similar to our findings. Our results (Table 3) show that the age-related increase in visual impairment found in the Beaver Dam Eye Study continues exponentially beyond the 86-year age limit of that study. It is probable that visual impairment in the oldest age groups has been slightly overestimated as a result of the higher nonparticipation rate among people 80 years of age or older (26%). Nonparticipants in this age group had better self-reported vision compared with participants, with a lower rate of glasses wearing (59% compared with 96%; $P < 0.0001$) and a lower frequency of reporting difficulty in seeing a person across the street (10% compared with 46%; $P < 0.0001$) but not for reading a newspaper.

Blind pension registrations have to date been considered the most reliable data in Australia[6] on blindness. However, these data are known to underestimate the true frequency considerably. Banks and Hutton[4] estimated that only half the eligible blind are on the blind or age-blind pensions, which may be because of the lack of a financial advantage in converting from an age to an age-blind pension.[5] In particular, blind pension registrations may underestimate the proportion of blindness due to AMD, found to be the principal cause in 88% of those with bilateral blindness in the present study. Of the 17 persons found to be legally blind, none were receiving a blind or age-blind pension. The most recent Australian blind pension data found that AMD was responsible for 52% of registrations, followed by glaucoma with 13%.[6]

Age-adjusted mean visual acuity scores were significantly lower among females who correctly identified on average two fewer letters than males. These logMAR visual acuity findings are strikingly similar to those found in the Beaver Dam Eye Study where age-specific visual acuity scores also were consistently and significantly lower in females, who identified on average three fewer letters on the logMAR chart after refraction than males. Another very similar finding in both studies was the significantly higher age-specific frequency of visual impairment in females compared with males.

Other previous U.S. studies: Framingham[14] and the Model Reporting Area[24] of the United States also found similar sex differences, but no difference was found in the multiracial Baltimore Eye Study[25,13] or in a study of the very elderly in three populations.[22] The cause of lower visual acuity in females at all ages is unclear, although there may be important different underlying etiologic factors for visual impairment in females compared with males. This also may be supported by a higher prevalence rate for age-related maculopathy among females.[26,27]

The major causes of visual loss in our study were AMD and cataract. This finding matches results from the Beaver Dam Eye Study.[28] It is of interest that in both studies, neither glaucoma nor diabetic retinopathy was a cause of bilateral blindness as in earlier reports.[29] This could reflect improved results from treatment for these two diseases, particularly for diabetic retinopathy.[30,31]

Major causes of monocular blindness were AMD, cataract, amblyopia, ocular trauma, retinal vein occlusion, and glaucoma. Other than AMD, these diseases are treatable or potentially preventable causes of blindness. The rate of unilateral blindness was significantly higher in males than in females, a finding also made in the Beaver Dam Eye Study.[12]

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